Density Measurements of Molten Minerals at High Pressure Using Synchrotron X-ray Radiography

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Introduction: Density of minerals is one of the key parameters for earth modeling. While density measurements of crystalline minerals at high pressure and temperature can be routinely carried out using in-situ diffraction techniques, experiments to determine density of melts at static high pressure are rare. Experimental technique has hindered us from studying equation of state (EOS) of molten minerals, which is essential for understanding earth especially earth's core. Density measurement of molten FeS is a particular important because FeS has been found in many meteorites and is believed to be a possible component of the cores of terrestrial planets such as Earth and Mars[1].

Methods and Materials: At the X17B1 beamline, we have developed a technique to measure density of melts at high pressure using monochromatic x-ray radiography. A digital radiograph records the intensity profile of transmitted x-rays through the high pressure and temperature cell: A thin YAG crystal screen converts the transmitted x-ray intensity linearly into visible light, and a digital CCD camera records the intensity of the visible light. For a known composition material, absorption of a monochromatic x-ray is only a function of density of the material and x-ray path length in the material. The absorption is determined from the intensity profile of the sample that contains a reference sphere (in this case corundum) whose absorption is known (Figure 1).

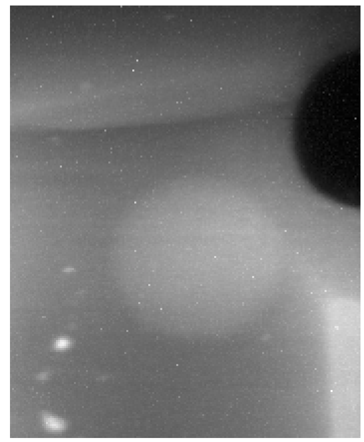

Figure 1. Radiograph of the sample assembly. A Al2O3 sphere is embedded in the FeS sample. Thermocouple junction is also shown at right-top corner of the image.

Results: In a pilot experiment, we studied the density of FeS at 5 GPa and temperatures up to 1500K. Density measured with the radiograph agrees with the x-ray diffraction density of the solid to ~1%. Density change associated with melting was observed in the signal. As this technique is applied to other materials, one must tune the x-ray energy and the reference material in response to the chemical composition of the material. Light elements require lower energies in order to have significant absorption in the sample compare to heavy elements.

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References: [1] Y. Fei, C.T. Prewitt, H.K.Mao and C.M. Bertka, Science 268 1892 (1995).